PHILOSOPHICAL TRANSACTIONS.

XIII. *Continuation of the Paper on the Relations between the Nerves of Motion and of Sensation, and the Brain; more particularly on the Structure of the Medulla oblongata and the Spinal Marrow.* *By Sir* CHARLES BELL, *F.R.S. &c. &c. &c.*

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IN this paper it will be necessary to enter on minute details of the anatomy; but they regard a subject hitherto untouched, although essential to the comprehension of the nervous system, without which, indeed, it could not be said that we had a knowledge of the nerves as a system.

The author has advanced, by slow and laborious researches, from observing the general arrangement of the nerves as they lie in the body, to the investigation of particular nerves and their endowments; and, finally, to the examination of these parts in the centre of the system, the brain and spinal marrow, which enables him to assign the reason of that perfect symmetry which reigns through the whole.

The subjects of his last paper have been examined again and again by dissection, and reviewed in every aspect. They have been found correct in every particular. But they necessarily lead to further investigation: they point more especially to a minute inquiry into the structure of the spinal marrow, and its relations to the encephalon on the one hand, and to the origin of the nerves on the other.

It might be imagined that the author of this paper had, in these inquiries, followed his preconceived notions; but it has not been so. On the contrary, when in search of the explanation of certain phenomena, he discovered a fact in the structure which diverted him from his design, and carried him in a new course of inquiry *.

In an anatomical investigation of so much delicacy, it is necessary, in order to understand the descriptions, that he who follows it by dissection should have the parts presented exactly in the same aspect, and trace them in a prescribed manner. When

* The paper on the Voice was undertaken as a preface to the investigation of the accessory respiratory nerves. In following that subject, the author found it indispensable to deviate into this inquiry, which proves to be the more important of the two.

the anatomist has recognised the parts, and verified the descriptions of the author, he will of course vary his mode of proceeding to satisfy himself.

Lay a portion of the spinal marrow, of two or three inches, on the dissecting board, and pin it so as to look upon the posterior surface of that cord. Begin by making a clean transverse section of it near one extremity, and inspect the newly-divided surface (see Plate III. fig. 1.). The first thing which we distinguish is the cineritious matter in the centre of the medullary. If we introduce the curette into the softer cineritious matter, we can separate the medullary columns (as in figg. 2. & 3.), and we distinguish these parts: the posterior columns, deeply divided by their sulcus; the lateral columns; and the anterior columns.

In making these divisions, directed by the natural sulci and by the cineritious matter, we may soon satisfy ourselves that there is but one absolute bond of union by nervous matter. We find the anterior columns tied together by a sort of commissure, and to that commissure is attached the anterior portion of the posterior columns at two points (fig. 3. D.).

Having contemplated the section of the spinal marrow, we proceed to the dissection by splitting up these columns. We raise the posterior columns together, in one piece; to do which we must divide them at the point of union with the anterior columns (fig. 4. B.). But except at this angle, the whole tract is raised without the slightest breach of its proper surface. When the columns are thus separated, the surfaces are found to be covered with cineritious matter. We have split the cineritious substance, and some of it lies on the lower surface of the part raised, and some on the upper surface of that which is below.

If we now clear away the cineritious substance from the columns below, we shall first discover the two lateral tracts or columns. We see them in their course, regular as nerves. These columns or cords, in this aspect and condition, take a rounded form, although they are of a different shape when packed together in their natural state.

And now may be observed a structure which is not without interest. If we make a slight breach upon the surface of the columns when divested of their cineritious covering, and insinuate the point of the curette, we raise a thin pellicle, like a distinct coat, and which we may separate all round. Having done this, and the remaining surface being smooth, we may pierce it again, and in a similar manner separate a third and a fourth layer, which, smooth and delicate themselves, leave the part below as regular as the natural or exterior surface. It appears that the superficial layers furnish the roots of the higher nerves, and that the lower layers go off into the roots of the nerves as they successively arise.

If we now follow the sensitive or posterior roots of the spinal nerves towards their origins, we find them entering and dispersing in the substance of these lateral columns. Some authors describe these roots as derived from the cineritious matter. This is quite at variance with my dissections. The cineritious matter is not of a con-

sistence or structure into which nerves can be traced: and through the whole column of the spinal marrow, up to the fifth and portio mollis of the seventh nerves of the head, the cineritious matter is superimposed on the columns and nerves *.

Between the lateral columns, the cineritious matter lies deep. Upon raising it, the anterior or motor columns are seen (fig. 4. D, D.). In essential circumstances they resemble the lateral columns, and they are distinct from them. The cineritious matter occupies a portion of the space between them; and as to the remaining part, the line of separation is distinct, and the surfaces are unbroken.

By the manner in which the dissection has been made, the posterior portion of the spinal marrow being raised, as it were, out of the heart of the cord, the remaining parts fall flat, and the lateral and anterior columns separate.

Having distinguished the columns which form the spinal marrow, their natural sulci, their proper connexions, and the distribution of the cineritious substance between them, we have in the next place to observe how these columns are arranged, and what change they undergo in the upper portion of the cord, called medulla oblongata. We approach from below the same parts which we looked upon in their relations with the brain in the last paper.

We must now have before us a portion of the spinal marrow with the medulla oblongata attached to it, and proceed with the dissection.

The parts being presented in the same aspect as before, we raise the two posterior columns, separating them from the others at the intervening cineritious matter. At the back of the medulla oblongata we find the posterior columns diverging, and forming the triangular space of the fourth ventricle; this space is laid open on tearing up the pia mater, which connects the cerebellum with the medulla oblongata. Each of these columns is now seen to consist of two, the outermost the larger, and that towards the central line the smaller, and in shape pyramidal †. Following up these diverging columns, we recognise them to be the processus cerebelli ad medullam oblongatam. These great tracts, which form a large portion of the spinal marrow, are now seen to bear relation to the cerebellum.

The posterior tracts or columns being raised, we have only the lateral and anterior columns, which belong to the cerebrum, to attend to. And here is the interesting part of this communication.

Once more observing the layer of cineritious matter, we brush it off from the

* It is easy to trace the roots of the sensitive portion of the spinal nerve into the lateral column. It should be observed at the same time, that in raising the posterior columns, by insinuating an instrument into the cineritious intermediate substance, there is a more intimate attachment of the medullary substance of the posterior column at its outer edge and in the line of the origins of the nerves. It is not impossible, therefore, that the posterior column may be connected with the sensitive root of the spinal nerves, though hitherto I have not traced the fibres.

† This subdivision of what I have called the posterior column of the spinal marrow is to be traced in the whole length of the spinal marrow.

lateral columns. This grey matter may be traced into the fourth ventricle, extending over the parts to be presently described, and over part of the roots of the fifth pair of nerves. It constitutes one sheet of matter from the cauda equina to the roots of the auditory nerves, and forms a grand septum between the anterior and lateral part of the spinal marrow which belongs to the cerebrum, and the posterior columns which are related to the cerebellum.

Union of the lateral Columns in the Medulla Oblongata.

On brushing away the cineritious matter from the cerebral portion of the spinal marrow, we recognise the two lateral columns. Upwards, or towards the brain, each of these columns has a double termination; first, in the root of the fifth nerve; and secondly, in the union of the columns, or, in other words, in their decussation.

These columns lie separate in the spinal marrow; but having ascended to the medulla oblongata, they fall together, and form one round column something less than half an inch in length. On tracing this united column upwards they are disentangled, but do not separate, for they now constitute those processes of the cerebrum which, in a former paper, we traced down from the back of the crura cerebri (fig. 5. E, E; fig. 6. A, A.).

On observing the portion of the united columns, the appearance is very much that which is presented by the union of the optic nerves; that is, however, rather when the part is thoroughly hardened in spirit: when it is somewhat more pliant, we can trace the filaments of one side into the column on the other side*. The decussation is the most perfect of any to be demonstrated in the brain and nerves.

Reverting to the statement in the former paper, that a septum divides the right and left sensitive tracts where they are seen in the fourth ventricle, and that in tracing that septum downwards it terminates at the point of decussation of these tracts: I have now to add, that the septum does not absolutely terminate, that it splits to permit the oblique course and decussation of the filaments of these columns. Thus separated at the union of the columns, the septa unite again below, and may be followed downwards into that connexion which binds the posterior portion of the spinal marrow to the anterior columns.

It remains a desideratum to know what is the nature of those fibrous septa which intervene and divide the longitudinal tracts of nervous matter. But whatever may be determined on this point, it is obvious that they form a perfect link or bond of union and mechanical strength, extending from the pons to the cauda equina. Around the commissures the fibres of these bands are especially interwoven†.

* Much of the anatomy, as I have here described it, may be made out in the recent parts. But it will be easier and more satisfactory, when the parts are soft, to drop them into spirits, so that the surfaces as they are exposed may be hardened and prepared for further dissection on a succeeding day.

† The true distinctions between the columns in the spinal marrow may be made, as we did those of the medulla oblongata, by observing the splitting of the septa. From the circumstance of the columns scaling off

When the two tracts or columns which descend from the posterior portions of the crura cerebri are transversely divided, where they form the slit of the calamus scriptorius, and when they are dissected down (fig. 4. A, A, B.), we obtain a very interesting view of the back part of the anterior columns (fig. 4. D, D.), or rather of the pyramidal bodies, and their decussation. We see the union and decussation of these bodies before they separate and descend to form the motor columns of the spinal marrow. The motor and sensitive columns,—which were close together in the crura cerebri, and which in their descent were separated in the pons, and by the septum which is continued down from the posterior transverse septum of the pons,—come here again into contact at the point of union and decussation*. The motor columns approach the sensitive columns, but no union takes place; the columns keep their respective courses down the spinal marrow. When we dissect these parts carefully at the back of the medulla oblongata, we may feel, and with sharp eyes we may see, very minute and yet uncommonly strong filaments which run among these parts. We may consider such filaments as a further proof how carefully these textures are guarded against laceration.

When the dissection is carefully made, we have thus a view of the posterior part of the decussation of the pyramidal bodies; and after their decussation we see them separate and descend in the two anterior or motor columns.

Concluding view of the Sensitive and Motor System of Nerves.

If it could be said hitherto that the distribution of the nervous system, more than any other part of the animal structure, evinces design, the conclusion is irresistible, when we perceive that the parts which minister to sensation and motion are arranged with a symmetry beyond what we expect to see in architectural plans or ornaments, where every part is balanced, and each has its counterpart.

It could not be well imagined that sensation and motion belonged to parts separate and dissimilar. Formerly I believed that the nerves of sensation, that is to say, the posterior roots of the spinal nerves, came from the posterior columns of the spinal marrow, and consequently from the cerebellum. Whilst entertaining this belief I found my progress barred, for it appeared to me incomprehensible that motion could result from an organ like the cerebrum, and sensation from the cerebellum, for there was no agreement between them. They conformed neither in size, shape, nor subdivisions. Sensation and volition are necessarily combined in every action of the frame†. Although these influences, of whatever nature they be, are pro-

in regular pellicles, we may else be deceived. On separating, for example, the posterior and lateral columns at the true sulcus of separation, we shall see the minute transverse fibres: which appearance is produced by the splitting of the septum. See the former paper.

* The motor and sensitive columns do not mix or decussate, but only the motor columns with each other, and the sensitive columns with each other.

† This has been illustrated in former papers, and particularly in treating of the actions of the lips.

jected in different directions, and belong to distinct filaments*, they must be finally conjoined and in union. The anatomy conforms to this idea; the cords of communication between the seat of volition and the organs of the body proceed from a centre, run parallel, undergo similar changes, and are blended in their ultimate distribution, as in their central or cerebral relations.

It is pleasing to see that through the labours of members of this Society the principles which have directed the author in the investigation of the human anatomy are likely to be extended in their application, by a correspondence being observed in the arrangement of the nervous tracts through every class of animals possessing volition. It has long appeared to the author that the system does not differ, even in the different classes of animals, although there is much apparent variety in the distribution of the nerves.

When it became a question whether or not *Crustacea* possessed the organ of hearing, the celebrated Scarpa undertook the investigation. With this purpose he did not pry about to discover the external organ of the sense. He looked to the brain, or cerebral ganglion,—recognised the part from which the acoustic nerve should come, according to the analogy of other animals. He found the nerve, and traced it to its destination; that simple rather than imperfect organ, which, but for the circumstance of the auditory nerve in its cavity, might have been supposed too defective in its organization to be capable of receiving the impulse of sounds.

In this manner is the nervous system to be studied; for there is an internal change, in accordance with outward organization, whilst the system or great plan does not vary. There is an endowment in each particular column; it is one through its whole course. An animal, or a class of animals, may have a particular organ developed, and with the external apparatus there is a corresponding or an adjusted condition of the appropriated nerve. Another class may be deficient in the external organization, when we shall in vain look for the accompanying nerve; it is contracted, or hardly visible; but with all this the system is unchanged.

From a more cursory view of the comparative anatomy than others may have taken, this is my conclusion; but my time for such investigations has been given almost exclusively to the human anatomy; and in it I hope it will be granted that the system, as it regards sensation and motion, has been displayed so as to increase the interest of these pursuits, and to direct the studies of the pathologist to beneficial results; much advantage could hardly have been expected by dissection of the brain, even from the utmost ingenuity of research, whilst the very elements of the subject, as regards the natural anatomy, were unknown.

* See the paper on the Nervous Circle.

Fig. 1.

Fig. 2.

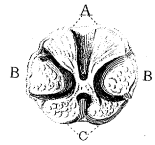


Fig. 3.

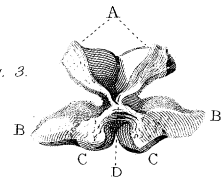


Fig. 4.

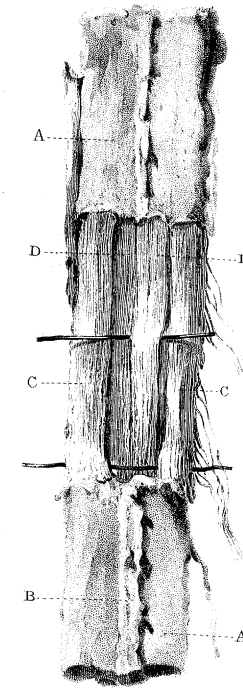


Fig. 5.

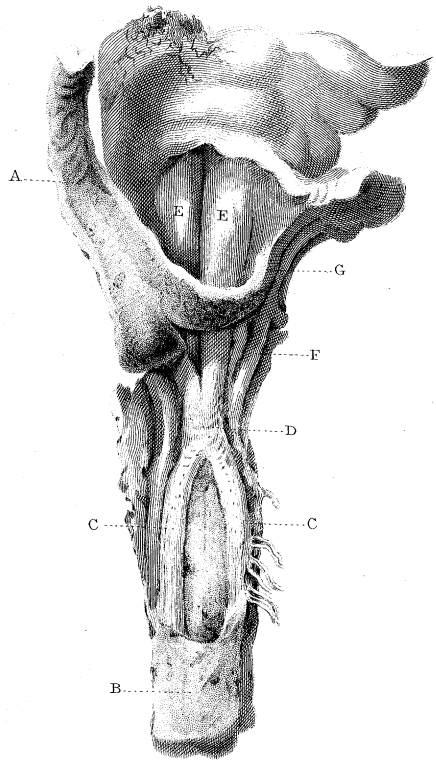
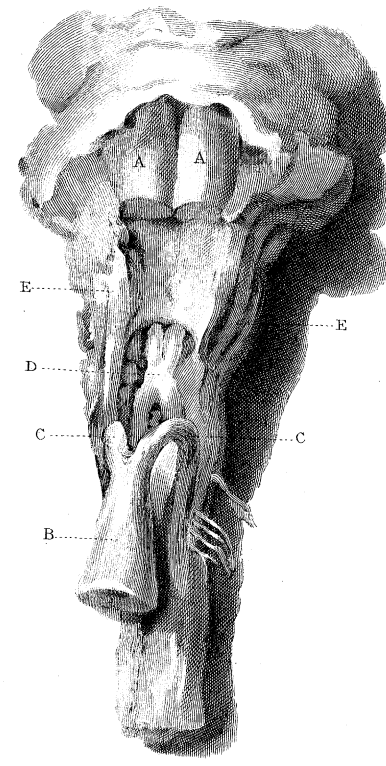


Fig. 6.



Drawn by Sir Cha.s Bell.

Engraved by J. Basire.

Explanation of the PLATE.

PLATE III.

Fig. 1. A transverse section of the spinal marrow, showing the distinctions of the medullary and cineritious substance.

Fig. 2. Shows the section with the medullary columns parted at their natural divisions, viz. by insinuating the curette into the cineritious substance, and opening the sulci.

A. The posterior column.

B, B. The lateral columns.

C. The anterior columns.

Fig. 3. The same parts still further separated, so as to exhibit the connexion between the posterior columns of the spinal marrow and the motor columns. The letters refer to the same parts as in the last figure.

D. The connexion between the posterior and anterior columns.

Fig. 4. In this view the posterior part of the spinal marrow, that which belongs to the cerebellum, is taken away, leaving those columns only which belong to the cerebrum. As the posterior portions (figg. 2. & 3. A.) enter deeply into the spinal marrow, when they are taken away the remaining columns fall flat on the board, and permit an easy separation.

A, A. The cineritious matter which intervenes between the columns belonging to the cerebrum, and those belonging to the cerebellum.

B. Projecting lines where the posterior columns of the spinal marrow were connected with the anterior. (See fig. 3. D.)

C, C. The lateral columns, or sensitive columns, after raising the cineritious substance. Into these the sensitive roots of the spinal nerves are traced.

D, D. A deeper dissection of the cineritious substance exposes here the posterior surface of the anterior or motor columns.

Fig. 5. This figure represents a posterior view of the upper part of the spinal marrow, and the medulla oblongata.

A. The two posterior columns of the spinal marrow being dissected up, they are here represented diverging towards the cerebellum at G.

B. The cineritious matter left on the remaining part of the spinal marrow, after raising the column (A.). The separation of the columns having been made at the intervening cineritious matter, both surfaces have that matter attached to them—both A and B.

C, C. The lateral columns of the spinal marrow (figg. 2. & 3. B, B.), displayed on their posterior surface. They are discovered on raising the cineritious matter B. Into these columns the posterior root of the spinal nerves are traced: they are the columns of sensation.

D. The short column formed by the union of the columns C, C. On dissecting this portion, the decussation of the columns will be seen.

E, E. The same columns which were lateral in the spinal marrow, now continued upwards, and visible in the fourth ventricle without dissection. They ascend under the valvula cerebri and under the corpora quadrigemina, and fall into the crura cerebri. So that, tracing them from above, each of these columns descends from that part of the crus cerebri which is posterior to the corpus nigrum.

F. The origin of the sensitive root of the fifth nerve of the encephalon.

G. The processus cerebelli ad medullam oblongatam.

Fig. 6. This figure represents the further dissection of the parts seen in fig. 5.

A, A. The columns marked E in the former plate. They are divided transversely, and the lower portion folded down, being separated from the parts below by a delicate dissection.

B. These columns folded down.

C, C. The lateral columns of the spinal marrow continued up into B.

D. The union of the anterior columns seen in their posterior aspect. The lateral or sensitive columns, and the anterior or motor columns, are held together at this point. But it appears more for security than reunion. A fine dissection exhibits them quite distinct; and the parts above continuous into the columns of the spinal marrow; each separately.

E, E. The sensitive roots of the fifth pair of nerves.